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CLASTIC HURONIAN ROCKS OF WESTERN ONTARIO

BY

ARTHUR P. COLEMAN

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CONTENTS

	Page
Results of previous work in the region	223
Classification of the rock series	224
Huronian clastics	224
General statement as to origin	224
Keewatin rocks	224
Couchiching rocks	225
Relation of Keewatin to Couchiching	227
Thickness of the Huronian series	227
Field relations of Laurentian and Huronian	228
Sections through pre-Cambrian mountains	229
Geological history of the region	231
Comparison with other regions	231
Cause of these mountain structures	232
Extent of the batholitic region	233
Concluding observations	235
	238

RESULTS OF PREVIOUS WORK IN THE REGION

The rocks of western Ontario have been more or less carefully examined by several geologists, such as Bigsby, Bell, and Dawson, but the first detailed mapping of the region was done in 1883 and succeeding years by A. C. Lawson, who laid an excellent foundation for the future study of the Lake of the Woods and Rainy Lake districts.* Since then adjoining districts have been mapped by W. H. C. Smith and W. McInness, and special portions have been studied by H. L. Smyth, Winchell and Grant, and the present writer. The general conclusions reached by Lawson have been commonly accepted by those who have followed and will be made use of largely in the present paper, though most of the

*Geol. Survey of Canada, 1885, part CC; and 1887, part F.

facts employed have been observed by the writer while engaged in field work for the Ontario Bureau of Mines.

Classification of the Rock Series

Lawson describes the region as wholly Archean, and divides the rocks into two parts—a lower one, the Laurentian, and an upper one, the Ontarian, further subdivided into the Couchiching and the Keewatin. The term Laurentian is used here in a petrographic sense, to denote a series of entirely crystalline, generally acid, rocks, especially coarse grained gneisses and granites, in spite of the fact that these rocks have an eruptive contact with the overlying series, and so are later in age than the Ontarian.

The Couchiching rocks, found chiefly in the southern portion of the region along the boundary of Minnesota, consist in general of monotonous gray or brown mica-schists and gneisses, sedimentary in origin.

The Keewatin, which overlies the Couchiching where the latter is present and in other cases rests on the Laurentian, is largely composed of eruptives and their products—schists resulting from shearing, ash rocks, and agglomerates—basic in the lower part, acid in the upper.*

Lawson does not definitely correlate the Couchiching with either the Laurentian or Huronian, but Van Hise includes at least part of it in the Basement Complex.† Lawson puts the Keewatin doubtfully with the Huronian, pointing out numerous differences between it and the original Huronian as described by Logan. In general, however, Canadian geologists do not hesitate to class these altered eruptives and the accompanying sedimentary rocks as Huronian, and this usage will be followed in the present paper.

In the first place the Huronian clastics will be briefly described, and afterwards the relations subsisting between the series of rocks and their causes will be discussed. The term Archean will be used to include both Laurentian and Huronian (or Ontarian), though according to the classification adopted by the United States Geological Survey the latter would be included in the Algonkian.

Huronian Clastics

General statement as to origin

As to origin, the Archean clastic rocks of western Ontario are of three kinds—pyroclastics, autoclastics, and sedimentary rocks proper.

The pyroclastics, consisting of agglomerates, ash rocks, etcetera, are of

* Geol. Survey of Canada, 1887, p. 22, F, etc.
† Principles of pre-Cambrian Geology, p. 782.

great extent and importance, but have no special bearing on the subjects of this paper, and so need no extended description. It is probable that some rocks mapped as agglomerates are really autoclastic, especially those including fragments sharply angular in form and all of the same kind. These angular blocks of rock could hardly have been hurled into the air as bombs. Lawson mentions transitions between agglomerates and true conglomerates with waterworn pebbles, which might readily occur where volcanic materials drop into the sea.

The autoclastics are not very extensive and will merely be mentioned. They are produced by the action of crushing and shearing forces in rocks above the level where pressure produces plasticity, and so give a hint as to the original depth of the rock beneath the surface. The best examples known to me, omitting the eruptives already mentioned, are the limestone breccias of Steep Rock lake and certain conglomerates to be seen a mile west of Fort Frances, where in the sharp folding of thin beds of sandstone between layers of schist the latter has yielded plastically, while the former was broken to fragments now embedded as pebbles in the schist.

The ordinary clastics, true sediments, are of special interest as giving clear ideas of the conditions of the time, and so will be described more at length than the two previous groups. The Keewatin, though very largely of eruptive origin, contains important sedimentary members, and the Couchiching is wholly sedimentary.

KEEWATIN ROCKS

The water-formed clastics of the Keewatin are of great variety, including limestones, slates, quartzites, grits, graywackes, breccias, and pebble and boulder conglomerates. The limestones are, however, of limited extent, being found in any thickness only at Steep Rock lake, 70 miles east of Rainy lake, where there is a small area differing both petrographically and structurally from the rest of the region. These limestones have a very modern look, being scarcely at all crystalline in appearance, having cherty layers in gray limestone at some points and black, very carbonaceous beds at others. One almost expects to discover fossils in them, but none have been found. They have been folded in an extraordinary way into an anticline and syncline having their axis inclined 60 or more degrees.*

The slates are widespread, passing often into phyllites. Many of them contain carbonaceous matter, and some examples have a graphitic look and soil the fingers. One of them, from an analysis by Dr Adams, was

*H. L. Smyth: Geology of Steep Rock lake. Am. Jour. Sci., vol. xlii, 1891, pp. 317–331.

found to contain 7.44 per cent of carbon, and is porous as though hydrocarbons had volatilized leaving round cavities.*

These carbonaceous slates may be compared with the black slate of the Sudbury region, in which Dr Ellis has found 6.8 per cent of carbon, and which was at one time bituminous, as shown in Balfour township by a large vein of anthraxolite, once no doubt a fluid or plastic petroleum product.†

The widespread graywackes need only be mentioned, since they present no points of special interest, and the same may be said of the somewhat unusual quartzites and grits, but the conglomerates are of more importance. They are found in many localities, but only one example will be taken for description, that of Shoal lake, more thoroughly studied than the others because occurring close to a number of gold-bearing veins.

As seen on the shore of the lake, it is a schist-conglomerate consisting of green chlorite as a matrix, with well rounded pebbles of all sizes up to two feet in diameter embedded in it. That this portion of the conglomerate has undergone shearing is shown by the flattening and even tailing out of some of the softer pebbles and the breaking and shifting of the parts of some of the harder ones. The commonest rock species in the pebbles are quartz-porphyry and porphyrite, felsite, and green schists indistinguishable from adjoining Keewatin schists. In addition, there are fragments of black and red quartzite and of white, pulverulent sandstone, of vein quartz and of anorthosite. No gneiss or granite has been found after careful search, though some quartz-porphyries having the crystals of felspar and dihexahedra of quartz much crowded, look, at first glance, very like granite. Most of these pebbles are easily matched by Keewatin rocks, sometimes, however, many miles distant; a few are evidently Couchiching, and none are Laurentian. One rock, a quartz-porphyry, half made up of beautiful spherulites having feathery intergrowths of quartz and felspar, has not hitherto been recognized in Ontario.

Two or three miles north of Shoal lake and some distance across the strike the rock becomes much less schistose, has a coarse grit as matrix, and might almost be described as a breccia, since many of the pebbles are scarcely rounded. The pebbles are, however, of the same rock species as those on the shore of the lake.

This band of conglomerate is at least 16 miles long and 2 miles wide. Its thickness can hardly be less than a mile and may be almost double that, since the dip is steep, but a covering of sand prevents very accurate measurements of the width. A very similar conglomerate appears on the east shore of Upper Manitou lake, 50 miles to the north, containing por-

*Geol. Survey of Canada, 1885, pp. 58, 124, and 150, CC.
†Ontario Bureau of Mines Report, 1896, p. 159, etcetera.

phyry, felsite, quartzite, etcetera, and a fine example is found at Rat Portage, the matrix in this case, however, being sericitic instead of chloritic. Numerous other instances are found in various parts of the region. No pebbles which are undoubtedly Laurentian have been reported from any of them, though granite boulders are found, as, for example, near Abrams rapids, north of lake Minnetakie. They resemble closely eruptive granites piercing the Keewatin in neighboring localities, and differ in appearance from the characteristic granite of the Laurentian.

COUCHICHING ROCKS

The Couchiching rocks are all formed of sand or clayey sand more or less metamorphosed. The least changed were found by the writer on the shore of Rainy river a mile below Fort Frances and at the Scramble mine near Rat Portage. They form thin beds of yellowish or brownish soft sandstone lying between micaceous and chloritic schists. Under the microscope, beside grains of quartz there are particles of magnetite and numerous small prisms, probably of tremolite. In general, however, the Couchiching consists of biotite schist or gneiss, the quartz showing a clastic origin. Some of these schists contain sillimanite; more rarely they appear as thoroughly crystalline gneiss containing muscovite, microcline, etcetera, resembling the adjoining Laurentian and forming transitions toward it.

The Couchiching includes no coarse clastics and is nowhere separated from the underlying Laurentian by a basal conglomerate. These rocks have been mapped by Lawson, Smith, and McInness as covering extensive areas in the southern part of the region. Rocks of a similar kind occur on Manitou lake, near the lake of the Woods and at other points, but have not been separated in the mapping.

Relation of Keewatin to Couchiching

Lawson suggests that the Shoal Lake and other conglomerates represent the base of the Keewatin, and so indicate an unconformity between the Keewatin and the Couchiching;* but the finding of many Keewatin pebbles in the conglomerates opposes this view. A striking evidence that the break represented by these conglomerates comes high up in the Keewatin instead of at its base just above the Couchiching is to be found at Shoal lake, where a few boulders of coarse-grained anorthosite found in the schist conglomerate are exactly like portions of a boss of anorthosite two miles away. As this anorthosite area contains masses and strips of characteristic Keewatin schist swept off during its eruption, it is evident

*Geol. Survey of Canada, 1887, p. 84, F.

that an immense lapse of time separates the conglomerate and the underlying Keewatin, long enough for a coarse-grained plutonic rock to solidify, probably at considerable depths, and then for the region to be so profoundly eroded as to provide pebbles of the plutonic rock on a seashore. It is probable that the Keewatin conglomerates which have been referred to represent an important interval of erosion, perhaps equivalent to the one shown to exist by Van Hise and others between the upper and lower Huronian in the states to the south.*

Nevertheless the striking difference in the character of the rocks of the two series, wholly sandy sediments in the Couchiching, largely diabase and porphyry and the products of their alteration in the Keewatin, shows that conditions had greatly changed before the later series was formed.

It must not be assumed, of course, that all of the eruptives found in the Keewatin were surface flows of the same age as the enclosing rocks. Many of them are probably of the nature of laccolitic sills like the trap sheets in the Animikie near Thunder bay. In fact, but for the undoubted pyroclastic rocks among the sediments one might suspect that most of them were injected between the sedimentary beds, perhaps at a much later date, since no amygdaloidal varieties have been found. In a region where there has been so much folding and shearing it is rash to make positive statements on such matters, however.

Thickness of the Huronian Series

Lawson estimates the thickness of the Keewatin at about 5 miles,† and of the Couchiching at about the same;‡ but W. H. C. Smith suggests for the latter that there may be a number of closely appressed folds not easily separated, so that the thickness of the Couchiching may be very much less, though still reaching 8,000 or 9,000 feet.§

Following Lawson's estimate, the two series together sum up to 50,000 or more feet in thickness, though it is probable that the lowest beds of the Couchiching have been dissolved by the molten Laurentian rocks beneath, since no basal conglomerate has been found; and also that there has been a considerable amount of compression during the squeezing undergone in the sharp synclinal folds, as proved by the flattening of soft pebbles in the conglomerates.

The Couchiching, containing some little consolidated sandstones, can scarcely be included in the Laurentian; and as it forms transitions to

* Journal of Geology, vol. i, No. 2, p. 120.
† Geol. Survey of Canada, 1887, p. 55, F.
‡ Ibid., pp. 101 and 102, F.
§ Ibid., 1890-'91, pp. 54 and 55, G.

rocks recognized as Keewatin, and lies conformably, so far as observed, beneath the latter, there seems no reason why the two together should not be classed as Huronian.

The Huronian of western Ontario presents, then, an immense series of shallow-water sediments, in the upper part mixed with eruptives, perhaps largely later injections, but partly pyroclastic; the whole equal in magnitude to the thick series of clastics found in the preparatory troughs of great mountain ranges, such as the Appalachians and the Rockies.

Field Relations of Laurentian and Huronian

The field relations of the Laurentian, Couchiching, and Keewatin have been so admirably shown by Lawson that only a brief summary will be required here. He was struck by the fact that the lower Archean "occurs in large, isolated, central areas more or less completely surrounded by the schists of the upper Archean, the encircling belts anastomosing and forming a continuous meshwork."*

An examination of the Rainy Lake region, where the innumerable bare shores of islands and promontories give an unsurpassed exposure of the Archean, shows that the Laurentian consists chiefly of coarse reddish, often porphyritic rock, usually granite in the central part of the area, but showing foliation toward the margin where it comes in contact with the Huronian. The foliation of the gneiss is generally parallel to that of the schist beside it. Before the actual contact is reached one generally sees strips and fragments of the Huronian embedded in the gneiss, sometimes sharply angular, at others with softened outlines. Often the actual line of contact is hard to define, so mixed are the gneiss and the schist. Dikes of granite, pegmatite, or felsite generally run from the gneiss into the Huronian. Where the latter is Keewatin one usually finds it hardened into hornblende-schist instead of the more common chlorite-schist. The Couchiching rarely shows much contact metamorphism, though occasionally garnets and staurolites are developed.

The Huronian schists have almost always a steep dip away from the gneiss, seldom less than 45 degrees and often vertical, and are folded into sharp synclines.

The areas of Laurentian are of all dimensions from a mile or less in diameter to a width of 50 miles or perhaps even more, and are usually rounded in form. Good examples of the larger Laurentian areas are found in the one including the north arm of Rainy lake, nearly 50 miles long from east to west and 25 wide; and in the Grande Presqu'ile of the lake of the Woods, 30 miles in length from east to west and 18 in width.

*Geol. Survey of Canada, 1887, p. 142, F.

Of the smaller areas mention may be made of Sultana island a few miles from Rat Portage, famous for its gold mine. Here a boss of coarse porphyritic granitoid gneiss a mile in length by half a mile in width presents the same eruptive contact with the green Keewatin rocks as one finds around the larger masses. Another similar boss of coarse Laurentian granite was found by the writer at Caribou lake, east of the lower end of lake Manitou, the area being only about a square mile. Examples of intermediate sizes may be found on the Canadian Geological Survey's maps of the region.

Finer grained granites, generally showing no foliation on the edges of the areas, are common also both in Huronian strips and in the Laurentian; and many more small knobs and bosses than were mapped by Lawson in his somewhat hurried work will be found from time to time; such as the area of protogine containing so many gold-bearing veins at

FIGURE 1.—*Geological Map of Part of Western Ontario.*

Shoal lake. So far as known, these granite bosses are later than both Keewatin and Laurentian, having penetrated both. It is, however, not always easy to say whether a given rock is Laurentian or a later granite, and it is likely that the two are connected in origin and might be arranged as a consecutive series. Both Laurentian and other granites send off felsitic dikes into the adjoining rock, and in this way one may often discover the proximity of a gneiss or granite area a quarter of a mile before reaching the contact.

It is worthy of note, as observed by Lawson, that often the gneiss grows darker and more basic near the contact with basic Huronian rocks, as though some of the latter material had been incorporated in the underlying Laurentian.

The accompanying map, figure 1, will illustrate the geological relationships just mentioned. It has been pantographed from three map sheets issued by the Canadian Geological Survey—the Rainy Lake, Seine River,

and Shebandowan sheets—the work of Lawson, McInnis, and Smith. As the scale is small and the lake and river systems are complicated, it seemed wise to omit much of the topography so as not to confuse the geological boundaries. The portion mapped includes on its western side one of the most characteristic batholitic areas, though tracts to the north and west would serve equally well as illustrations if the geological sheets covering them had been published.

Only a few of the granite bosses are mapped, many being too small to be conveniently shown.

Sections through pre-Cambrian Mountains

Evidently this well glaciated Archean peneplain presents a most instructive section through the base of an ancient group of mountains. The sharp synclines of Couchiching and Keewatin nipped in between areas of gneiss and granite are merely remnants preserved because of their protected position. Often unfinished curves may be seen running out into the Laurentian, erosion having eaten below the bottom of the part that has vanished. Imagining these roughly circular or oval synclinal folds complete, we should see convex surfaces forming domes of diameters varying from 1 mile to 50 miles. What their height was in their prime one can hardly guess; but from their diameter and the steep dip of their synclinal portions one may suppose that the largest of these pre-Cambrian mountains were comparable with the greatest mountains of the present day.

The process by which they were built seems to have differed from that of later times in the earth's history, since they were not constructed of a series of parallel anticlinal folds, but were pushed up more like the laccolitic mountains described by Gilbert and Whitman Cross from the western United States, though with the difference that the up-pushing mass of molten rock was broad based.

While the larger areas of gneiss and granite are evidently batholites, some of the smaller granite bosses may be stumps of old volcanoes, though they could not have furnished the acid pyroclastics of the Keewatin through which they rise. Lawson looks on the Shoal Lake anorthosite boss as the stump of a volcano furnishing basic pyroclastics.*

Geological History of the Region

Reviewing the facts presented by the rocks of western Ontario, we find an oldest series, the Couchiching, consisting of sands and clayey sands

* Geol. Survey of Canada, 1887, p. 57, F.

deposited on a sea bottom, since entirely destroyed. The adjoining land must have presented an abundance of quartz-bearing rocks to furnish so many cubic miles of sand.

After at least a mile and a half and probably five miles thickness of these sands had been laid down in the southern portion of the region, the second or Keewatin series began, in which great eruptions of basic and acid rocks alternate with clays, grits, and conglomerates, the latter sometimes a mile thick. It is probable that an important break in the series is shown by the conglomerates. During the later part, if not the whole, of the time we may suppose that organisms existed, furnishing the large percentage of carbon found in some of the rocks.

Ultimately the sinking sea bottom was loaded with an eight or ten miles thickness of sediments and eruptive materials, as in the geosynclines preparing the way for later mountain ranges, and the slowly rising isogeotherms softened or fused the foundation, which rose into domes, the inner parts solidifying as granite, the outer more viscid portions having their constituents dragged into rough parallelism with the adjoining solid rocks and forming gneiss.

Comparison with other Regions

The usual theory of mountain-building, by lateral thrust due to the sinking in of the earth's crust to conform to the shrinkage of the interior through loss of heat or of volatile constituents, seems capable of producing only folds; and it is doubtful if thrusts in two directions at right angles to each other could produce anything except more complex forms of the same kind. The formation of irregularly placed domes demands some other cause.

One naturally compares these batholitic* mountains with the laccolites so distinctly brought before the world by Gilbert in his description of the Henry mountains of Colorado. There also there are oval domes, though not over 3 or 4 miles in diameter. Larger but more irregular ones are described by Whitman Cross from the adjoining western states. It is evident, however, that these cake-like masses of eruptive rock resting on their undisturbed floor of stratified rock differ greatly from the Rainy Lake mountain stumps, which are only more elevated portions of the general substratum of gneiss on which the sedimentary rocks now rest.

The eruptive masses described by Dawson from the Sweet Grass hills of northern Montana, tilting up "the previously horizontal beds of the plains," so that those immediately surrounding the igneous masses rest

* Bathylite is the form of the word preferred by Dana and Zirkel.

at very high angles,* seem more nearly related in general structure, and the same may perhaps be said of the extraordinary "plutonic plugs" described by I. C. Russell as pushing up the strata into domes in the Black hills of Dakota.† Probably some of the bosses of granite described in works on geology are of the same character, though many of them have a different relationship, pushing or fusing their way through overlying strata without becoming schistose themselves nor doming up the beds above.

The dome of the Black hills, as represented by Russell,‡ seems to come closest to the batholitic domes of western Ontario, though the section across the Black hills, copied from Newton and Gilbert, differs greatly from them in some points. As shown diagrammatically, the relatively small central plug of granite is surrounded by a wide band of vertical schist, on whose edges rests the dome of sedimentary rocks, as though there had been two upheavals, separated by a wide interval, during which the later sediments of the dome were deposited. The size of the Black Hills dome is greater than that of the west Ontario batholites studied up to the present, and the time of the latest uplift much more recent.

Cause of these Mountain Structures

Gilbert suggests for the laccolites that the ascending flow of molten rock rises only until the overlying rock is less dense than itself, when the latter is pushed up into a dome, the general law of hydrostatics being obeyed.§

Whitman Cross, following Dana, does not accept the hydrostatic theory, thinking that the force which set the lava in motion is sufficient to account for the facts.‖

I. C. Russell suggests "that uplifts which owe their origin to the intrusion of a molten magma into the rocks beneath them be termed subtuberant mountains. They may be fancied to originate from the growth of a tuber within the earth's crust."¶ He thinks that the cooling and therefore contracting crust of the earth brings pressure to bear on the hotter interior, squeezing upward the molten rock, which may either form domes without reaching the surface or come to the surface forming volcanoes.**

* Geol. Survey of Canada, 1882–'83–'84, p. 17, C.
† Journal of Geology, vol. iv, no. 1, p. 23 etc.
‡ Journal of Geology, vol. iv, no. 2, p. 183, etcetera. I have been unable to obtain a copy of the "Geology of the Black Hills" in time for use in preparing this paper.
§ Geology of the Henry mountains, Washington, 1877, pp. 72 and 95.
‖ Laccolitic mountain groups of Colorado, Utah, and Arizona-Washington, 1895, p. 241.
¶ Journal of Geology, vol. iv, no. 2, p. 189.
** Ibid., pp. 190, 191.

Suess thinks that eruptives of this sort cannot elevate the rocks above, but, on the contrary, can only occupy spaces already prepared by tensions in the earth's crust.*

Some of the methods referred to are obviously inapplicable to the batholitic type of mountains. Russell's suggestion of upwelling lavas urged by a squeezing action of the earth's crust can hardly be brought to bear on a region where the whole solid crust for thousands of square miles has been tossed into irregular domes. In fact it is difficult to see how any outside force can be applied in such a way as to elevate domes 50 miles across when the earth's crust adjoining is itself plastic. We seem forced to look for some force inherent in the masses themselves. If we look at the conditions we find that the granites of these batholites were probably fused hydrothermally, but not excessively hot, since blocks of basic Huronian rock, readily fused by a dry heat too low to melt granite, often lie in them with unrounded edges. Even at a relatively low fusion point they must have been much hotter and hence (potentially) lighter than the unfused rock above, particularly when the latter was basic like most members of the Keewatin series. This relatively light silicious magma, probably not thoroughly liquid, but only plastic, following the laws of hydrostatics crept upward where the load of overlying rock was smallest, the heavier Huronian beds meanwhile settling slowly into synclines between the rising batholites. The process may be conceived to have gone on very slowly under sufficient load to prevent violent disruptions of the overlying strata, since a certain plasticity of the beds is shown by the shearing observed, especially among the softer pebbles of the conglomerates.

The large porphyritic felspars observed in many of the gneisses and granites suggest two stages in the history of these rocks—an earlier one, before the ascent began, and the later slow consolidation. Augengneiss around the margin of batholites proves that the crystals existed before the shearing uprise was complete.

Some of the laccolites described by Gilbert show surprisingly perfect unbroken domes of stratified rock, and the same is true of the domes elevated by plutonic plugs; in both cases due, as suggested by Gilbert, to there having been load enough to prevent disruption. The amount of stretching undergone by the arched strata in the instances described was, however, not very great.

In the case of the larger batholitic domes of western Ontario the extension must have been as a rule much greater. The Grand Presqu'ile dome may have been comparatively low and flat, since a dip of only 24

* Antlitz der Erde, vol. I, p. 218, etc

degrees may be observed in Huronian schist resting on gneiss at the south of the batholite, and basic schistose rocks found in its interior west of Astron bay are perhaps remnants of the upper parts of the low arch of the dome.

In other cases where the dip of the schist is very steep or sometimes even tilted a little under the edge of the batholite, it is probable that the dome was much higher, and the stretching of the overlying strata must have amounted even to miles in large domes like that of Rainy lake.

Extent of the batholitic Region

The region whose geological history has just been sketched extends from the lake of the Woods on the west to lac des Mille Lacs on the east, a distance of more than 200 miles, with a width north of Rainy lake of 120 miles. Most of this large extent of country shows the mesh structure in a more or less typical way, though toward lac des Mille Lacs on the east the bands of Huronian tend to become parallel, suggesting an approach to the more normal folded mountain structure. Throughout this whole region the Laurentian has eruptive contacts with the Huronian, and nothing like a basal conglomerate of the Huronian can be found.*

It would be unwarranted perhaps to suggest that the relationships described are normal for the Archean, especially when relatively only a small portion of the immense extent of the Canadian Archean has been mapped with any detail, yet in a considerable number of instances similar relationships have been found.

Dowling maps imperfect mesh-like strips of Huronian about areas of eruptive gneiss and granite from the district of Keewatin † 80 miles north of the lake of the Woods, and Barlow states that the underlying gneiss has an eruptive contact with the Huronian in the Sudbury region 500 miles to the east of lac des Mille Lacs. Dr Bell, however, appears to differ from this view, explaining the relation of the two series of rocks, at Wahnapitae for instance, by assuming a fault.‡ My own observations near Sudbury and Wahnapitae convince me that at those points the contact is eruptive, since dikes of pegmatite, etcetera, may be seen passing

*Van Hise (Pre-Cambrian Geology, p. 786) follows Smyth in speaking of the Steep Rock Lake series as resting with a characteristic basal conglomerate on the eroded edges of the Basement Complex; but my own observations show this to be no exception to the general rule. The gneissoid granites which enclose the series form eruptive contacts with the Keewatin at the Harold Lake gold mine a few miles west of Steep Rock lake; and Smyth himself (Am. Jour. Sci., vol. xlii, 1891, p. 322) in describing the supposed basal conglomerate states that it contains large pebbles of quartz and greenstone, but mentions no gneiss or granite pebbles.

†Geol. Survey of Canada, 1894, part F.

‡Ibid., 1890-'91, p. 14, F.

from the gneiss into the green Huronian rocks. The loops so characteristic of the Huronian farther west are, however, to be seen only indistinctly, if at all, on Bell's map of the region. Adams and Barlow show the same relationships between the Hastings and Grenville series of eastern Ontario and the underlying Ottawa gneiss,* and Adams maps similar curving bands of the Grenville crystalline limestones sinking into the gneisses below, in his report on the Laurentian area north of the island of Montreal.† These two series are probably the eastern equivalents of the western Huronian, the Grenville series having undergone a more intense metamorphism than the usual Huronian. The conglomerates found by Adams prove that these rocks were undoubtedly of sedimentary origin.

Still farther east, in the great Labrador peninsula, Lowe describes crystalline limestones and garnetiferous, graphitic gneisses forming bands in the Laurentian, though his evidence as to the relation of the ordinary Huronian to the underlying Laurentian is not so conclusive. He recognizes in some of the mica-gneisses sedimentary beds like Lawson's Rainy Lake Couchiching, but in other places speaks of Huronian rocks as resting unconformably on the Laurentian, though in some cases they are more or less interfolded with the Laurentian.‡

On the other hand, according to Van Hise, Logan's original Huronian, north of the lake from which it got its name, seems to be of later age than the underlying Laurentian, since he finds basal conglomerates or breccias containing fragments of Laurentian rock at two localities.§ Barlow, who has examined the same region, thinks, however, that there also the contact is eruptive.

From Van Hise's admirable "Principles of North American pre-Cambrian Geology" one finds that a conglomerate of the Huronian rests discordantly on the foliated edges of the Basal Complex at many points south of lake Superior,‖ and Dr Dawson informs me that characteristic Huronian beds rest on an eroded Laurentian surface in New Brunswick.

It may be that at more southerly points the thickness of the Huronian series is considerably less than in the typical Archean region, and hence that the floor on which the sediments rested was not softened or fused, as happened farther north. On the other hand, it is not impossible that in the states south of the lakes rocks of a somewhat later age, resting on the upturned edges of the Archean (including the Rainy Lake Huronian) have been looked on as Huronian. Van Hise includes mica-schists, green

* Am. Jour. Sci., vol. iii, March 1897.
† Geol. Survey of Canada, 1895, part J.
‡ Geol. Survey of Canada, 1895, part L, p. 196, etc.
§ N. Am. Pre-Cambrian, 1896, p. 777.
‖ Ibid., p. 784.

schists, etcetera, of Lawson in the Basement Complex, on whose eroded edges the Huronian is supposed to rest.* As it seems generally assumed that distinctly clastic rocks, such as the little altered Couchiching sandstone of Rainy river, should not be referred to the Laurentian, it might be well for a small party of American and Canadian geologists interested in these questions to go over certain typical regions together, so as to come to a common basis of classification for these difficult formations.

However it may be in other regions, there is certainly a very large area in northwest Ontario in which the relations between batholites of granite and gneiss and the schistose rocks of Huronian (Ontarian or Algonkian) age are as described in the foregoing paper. Tens of thousands, if not hundreds of thousands, of square miles of the western Huronian were once afloat on a plastic granitic magma which swelled into great bubble-like mounds, while the colder surface rocks tended to sink into the spaces between; and a phenomenon of such wide extent deserves careful study, whether the explanation given above be correct or not.

It is worthy of note that in several regions where ancient sediments were supposed to rest discordantly on the Fundamental Complex more detailed study has proved that the contact is eruptive. The latest instance is described by R. A. Daly, who finds batholitic gneiss pushing through overlying mica-schist in New Hampshire.†

It is probable that wherever sediments accumulate to a thickness of 40,000 or 50,000 feet the beds on which they lie become plastic if not fused, shift their place to correspond to the load, and form eruptive contacts with the rocks above. As this has taken place beneath every great mountain range, perhaps aided by relief from pressure under anticlines, and is no doubt still taking place where preparations are being made for the great mountain chains of the future, a so-called Fundamental Complex is to be regarded, not as characteristic of great antiquity, but as resulting from a certain set of conditions which may exist at any age. The older mountain ranges, having been more deeply eroded, give an opportunity to study these gneissic and granitic cores, while in later ranges they are still buried out of sight. It is likely, however, that a basal section through our present mountain ranges would show long bands of gneiss and granite rather than approximately circular batholites, such as we find in western Ontario.

If the supposition just made be correct, areas of the Laurentian or Fundamental Complex do not represent the earth's *erstarrungskruste* but are merely portions of the earth's crust, of sedimentary or other origin, which have been buried deeply enough for hydrothermal fusion

* Pre-Cambrian Geology, p. 782.
† Journal of Geology, vol. v, no. 7, p. 694, etc.

and have afterward been disinterred by long continued denuding forces. Good examples of wide areas of granitoid rocks, merging at many points into gneiss and having an eruptive contact with the overlying rocks, are to be found, according to Dr Dawson, in the Coast ranges and Interior plateau of British Columbia,* but here the Basal Complex is of Jurassic age.

Concluding Observations

It will be observed that the term Laurentian has been employed in this paper as Lawson and other Canadian geologists are accustomed to employ it, in a petrographical and structural sense for crystalline gneissic or granitic rocks underlying the Huronian. That these rocks have consolidated at a later time than the Huronian is evident, and therefore they have not the position in time which Logan supposed when the name was given. It may be advisable to provide another designation for these widespread rocks, which occupy the same position structurally and are formed of practically the same materials as those to the south, whose attitude with reference to the Huronian corresponds to Logan's original Huronian.

How much of the 2,000,000 square miles of the Canadian Archean presents the same relationships as have been described in this paper, and how much shows the orthodox unconformity between Huronian and Laurentian can be determined only by careful field work. If the eruptive contact is the normal type and the Huronian which rests discordantly on the Laurentian turns out to be really later in age than Lawson's Ontarian, we must look on the Couchiching series as presenting the oldest known rocks. This would carry back the ordinary sedimentary deposit of sands and clays to the beginning of known geological time.

*Geol. Survey of Canada, 1886, part B, and 1894, part B.